

people may not modify their behavior to accommodate it. Also, homes in the Northeast, particularly in poorer areas that may lack air-conditioning, are red brick row houses with windows on only two sides and tar roofs, all of which trap heat. In contrast, in the South poorer people often live in frame houses with light colored roofs and windows on four sides, which helps mitigate the heat. The total number of "excess" deaths (above what would normally occur) in a given summer

relies on Philadelphia's framework for responding to hazardous weather conditions. Whenever the system predicts a heat wave, he explains, Philadelphia officials distribute media advisories, activate telephone hotlines, alert neighborhood volunteers, open air-conditioned shelters, expand outreach to the homeless, and coordinate efforts with local utilities or take other actions, depending on the level of risk predicted. "The information [generated by the computer program] is no good unless you have channels of communication in place so that you can act on a warning once you have it," he says.

Lawrence Robinson, deputy health commissioner for public health promotion at the Philadelphia Department of Public Health, says, "Putting into place an emergency response program involving a large number of agencies and individuals requires a rapid shift of personnel and resources. The UD system allows us to launch these special services exactly when they are needed to save lives."

Says Samet, "Implementation of the [UD] warning system in several areas can serve two purposes: we gain a prospective test of the system, and refinements can be made based on the findings." The systems, therefore, are "a first step in predicting days that may kill, and taking steps to prevent this from happening," he adds. Kalkstein estimates the cost of developing and installing the Italian heat warning system to be between \$50,000 and \$75,000.

Climate-controlled Disease?

According to a report issued by the American Academy of Microbiology, feeling "under the weather" may be a more literal circumstance than it seems. The report, entitled *Climate, Infectious Disease and Health: An Interdisciplinary Perspective*, is based on the findings of an academy colloquium held 20–22 June 1997 in Montego Bay, Jamaica. The colloquium was attended by researchers, professors, and representatives from diverse public health and government agencies who reviewed the current state of the knowledge of the effects of climate and weather change on human health, and developed recommendations for a future plan of action.

According to the World Health Organization's *World Health Report 1998*, infectious diseases killed more than 17 million people in 1997. Climate can influence the occurrence of infectious diseases in a number of ways, through temperature, precipitation, wind and ocean currents, and El Niño–Southern Oscillation (ENSO) sequence. Colloquium co-chair Jonathan A. Patz,

director of the Program on Health Effects of Global Environmental Change in the Department of Environmental Health Sciences at the Johns Hopkins School of Public Health, notes, however, that the interaction of climatic variables can be complex and unpredictable. "Predicted change in disease risk or transmission is not simple," he says. "Multiple factors must be considered."

Climate and weather conditions affect vectorborne diseases by influencing the reproductive success of the vectors that spread the diseases, and by altering the incubation period of certain mosquito-borne viruses. For example, warmer temperatures shorten the time needed for the virus responsible for dengue fever to become activated within its mosquito host. On the other hand, hot temperatures can also reduce the survival of mosquitoes and ticks. Warmer conditions also correlate with increased populations of some microorganisms that cause waterborne diseases, such as the *Vibrio cholerae* bacterium, which causes cholera. In addition, rainfall and flooding (which result in the watery habitats optimal for certain disease vectors and microorganisms) and runoff (which can transport pathogens from the feces of infected pasture animals) may also cause increased transmission of diseases among humans. Higher ambient temperatures foster the growth of pathogens that thrive in or on food, such as *Salmonella*. Some airborne diseases are believed to be affected by climate and weather conditions, as evidenced by their seasonal nature. For example, meningococcal meningitis (spinal meningitis) occurs in sub-Saharan Africa most frequently during the dry season from December through June, and subsides markedly during the rainy season.

While much may be known about individual diseases, colloquium participants agreed that there are serious knowledge gaps in understanding the complex relationship between weather, climate, and infectious disease. The report suggests three improvements to remedy these gaps.

First, data collection methods must be improved. Morbidity and mortality data-gathering methods around the world are far from standardized and may vary widely in reliability from region to region. The report suggests measuring genetic markers of particular microorganisms as a way to trace a pathogen through the ecosystem, and studying the influence of microenvironments (such as occur in underground storm drains and houses) on vector survival rates.

The report points to the ENSO Experiment as an example of effective cross-disciplinary collaboration. The ENSO



in Philadelphia was calculated by Kalkstein to be 129, versus 0 for Miami [EHP 105(1):84–93]. Kalkstein says

that each city has a particular heat threshold above which the number of deaths begin to rise. A key benefit of the UD system is that it is customized to reflect a given city's response to heat waves.

Jeff Moran, a spokesperson for the Philadelphia Department of Public Health, says the heat warning system seems to be working for his city. Its success, he says,

Experiment is a research endeavor that examines the relationship between ENSO and other climate-related phenomena and human health, and explores the potential for using climate forecast information to provide early warning of conditions posing a public health threat. The project is coordinated by the National Oceanic and Atmospheric Administration and was initiated in 1997 as a result of the colloquium. The ENSO Experiment studied the 1997–1998 ENSO then underway; today, studies sponsored by several different agencies continue to track the human health aftermath of that phenomenon.

Second, modeling studies must be undertaken to elucidate links between climate and infectious disease. According to the report, one of the primary goals of model building for research on weather–disease links is to be able to predict outbreaks of disease in response to particular climatic variables. The report says models are needed not only to organize and assess the new data that are being collected, but also to reassess data that are already available. Several new models are being developed, such as a model by Mercedes Pascual of the Center of Marine Biotechnology at the University of Maryland Biotechnology Institute in Baltimore, which will examine the predictability of cholera in endemic regions and its relationship to climate variability.

Third, the report stresses the need for collaboration among scientists, and between scientists and the public. The report calls for an international collaborative research effort and the establishment of new research centers specifically to study the relationship between climate, weather, and disease. The report also cites the need for increased and longer-term funding. Traditional research funding cycles run 2–3 years, which is in sharp contrast to the 25 years recommended by the report for a comprehensive study documenting the weather–disease relationship. The report particularly stresses the need to develop new weather–disease databases, linked nationally and internationally, that are interdisciplinary in content and accessible to all interested researchers, and

to link existing databases maintained by independent groups of scientists. The report points out that, while there are electronic data sets to be found all over the world, few of the existing databases are either coordinated or designed to be used in conjunction with others.

Finally, the report calls for the drafting of a shared terminology to unite scientists separated by language and discipline, and for scientific journals to publish weather–disease articles that straddle traditional disciplinary boundaries. The report also urges graduate and medical schools to implement courses in weather–disease studies, and encourages scientists to gain popular support for such research by educating the public through demonstration of the value of this research to society.

The When, Where, and How of Environmental Hazards

When the TV news forecasts sun but clouds loom instead, life goes on. People shrug, curse, and grab an umbrella. But when scientists try to predict global warming, earthquakes, or nuclear waste leaks, their uncertainty is much harder to shake off. Then there's the question of what to do in the face of such uncertainty. At the

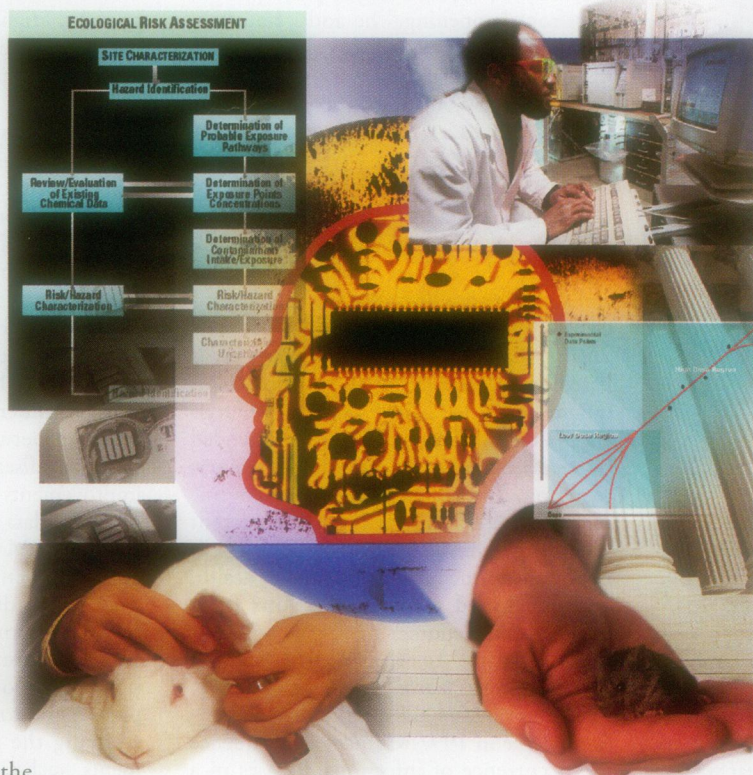
annual meeting of the American Association for the Advancement of Science, held in Anaheim, California, in January 1999, scientists debated the use and abuse of scientific predictions in environmental policy, as well as the traditional policy of erring on the side of caution when in doubt as to the nature and extent of environmental hazards.

In one session, scientists took turns revealing gaping holes in scientific prediction. For instance, Orrin Pilkey, a geologist at Duke University in Durham, North Carolina, and Daniel Metlay of the U.S. Nuclear Waste Technical Review Board lamented the decade-old dispute over storing radioactive waste under Nevada's Yucca Mountain. Under pressure to pick a spot for dumping the waste, Department of Energy policy makers put blind faith in mathematical models of pollution flux at the site, said Pilkey. Relying on these models for years, scientists didn't bother to draw water samples from under the mountain, he said, and when they did, they found it hard to predict whether the waste might in fact seep into groundwater. Following the discovery, political debates, scientific wrangling, and media headlines ensued. By then, Metlay added, the department's policy makers had become "hostages of time,"

struggling to meet federal waste disposal deadlines and relying on mathematical models to help do it.

There's a smarter route to environmental prediction, Pilkey and Metlay said—a tighter partnership between policy makers and scientists, complete with plenty of independent geology research for any proposed nuclear waste site, and less reliance on models. This call for better communication between scientists and policy makers resounded at the session, as the panel outlined uncertainties in global climate change, California earthquakes, and eroding North Carolina beaches. Better communication, said Daniel Sarewitz, a geologist at Columbia University in New York, "allows the policy makers to understand the limits of science, and it allows scientists to understand what policy makers need to know."

Such communication is not the current paradigm, said Sarewitz, who has worked as a consultant to the House of Representatives Committee on Science, Space, and Technology. He said that climate



Through a glass darkly. Predicting and quantifying risk from environmental hazards is still a somewhat murky science, but new paradigms may improve the accuracy of these exercises.